AP® Physics C: Mechanics
Multiple-Choice Answer Key

No.	Correct Answer
1	D
2	D
3	B
4	E
5	D
6	A
7	A
8	D
9	D
10	A
11	A
12	D
13	B
14	D
15	D
16	E
17	E
18	B
19	D
20	E
21	C
22	C
23	E
24	B
25	D
26	E
27	C
28	C
29	B
30	C

No.	Correct Answer
31	A
32	E
33	E
34	C
35	E

Question 1

15 points total | **Distribution of points**

(a) 5 points

For using a correct kinematic equation to determine the time of flight — 1 point

$v_y = v_{y0} - gt$

For correctly using the vertical component of the initial velocity — 1 point

$v_{y0} = v_0 \sin 30^\circ$

$0 = v_0 \sin 30^\circ - gt$

For a correct expression for the time — 1 point

$$t = \frac{v_0 \sin 30^\circ}{g}$$

$$t = \frac{(12.0 \text{ m/s}) \sin 30^\circ}{9.8 \text{ m/s}^2} = 0.61 \text{ s}$$

For a correct kinematic equation including correct use of the horizontal component of the initial velocity — 1 point

$D = v_x t$

$v_x = v_0 \cos 30^\circ = 10.4 \text{ m/s}$

$D = (10.4 \text{ m/s})(0.61 \text{ s})$

For the correct answer — 1 point

$D = 6.4 \text{ m}$ (or 6.2 m using $g = 10 \text{ m/s}^2$)

(b) 3 points

For applying conservation of momentum — 1 point

For correctly using the sum of the clay and block masses after the collision — 1 point

$mv_x = (m + M)v_f$

$$v_f = \frac{m}{m + M} v_x$$

$$v_f = \frac{0.20 \text{ kg}}{0.20 \text{ kg} + 2.3 \text{ kg}} (10.4 \text{ m/s})$$

For the correct answer — 1 point

$v_f = 0.83 \text{ m/s}$

Question 1 (continued)

Distribution of points

(c) 3 points

For applying conservation of energy — 1 point

$\frac{1}{2}(m+M)v_f^2 = (m+M)g\Delta h$

Solving for Δh

$\Delta h = \frac{v_f^2}{2g} = \frac{(0.83 \text{ m/s})^2}{2(9.8 \text{ m/s}^2)} = 0.035 \text{ m}$

For applying the correct trigonometry relating Δh and the length of the string ℓ — 1 point

$\Delta h = \ell - \ell\cos\theta$

$\theta = \cos^{-1}\left(\frac{\ell - \Delta h}{\ell}\right) = \cos^{-1}\left(\frac{3.0 - 0.035}{3.0}\right) = 8.8°$

For the correct answer — 1 point

$\theta = 8.8°$ (or 8.7° using $g = 10 \text{ m/s}^2$)

(d) 2 points

For correctly calculating the period — 1 point

$T = 2\pi\sqrt{\frac{\ell}{g}}$

$T = 2\pi\sqrt{\frac{3.0 \text{ m}}{9.8 \text{ m/s}^2}} = 3.5 \text{ s}$

For an indication that the requested time is one-half the period — 1 point

$t = \frac{1}{2}T = 1.7 \text{ s}$

(e) 2 points

For correctly indicating that the new angle is greater — 1 point

For a correct justification — 1 point

For example: Substituting the expression for v_f from part (b) into the first expression for Δh from part (c): $\Delta h = \frac{1}{2g}\left(\frac{m}{m+M}\right)^2 v_x^2$

Increasing the mass m increases the height achieved by the pendulum; hence, the resulting angle is greater than that achieved with the original mass.

Question 2

15 points total **Distribution of points**

(a)

(i) 1 point

For a correct determination of the average force 1 point

$$F_{avg} = \frac{(0.84 + 0.85 + 0.84 + 0.83 + 0.85)\text{N}}{5} = 0.84 \text{ N}$$

(ii) 1 point

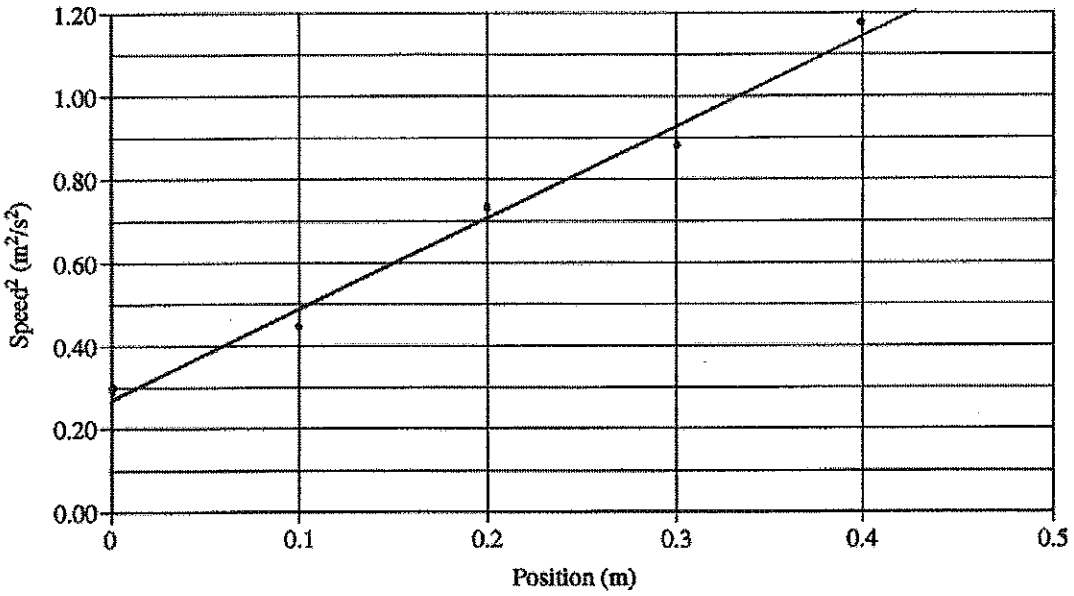
$W = F_{avg}x$

$W = (0.84 \text{ N})(0.40 \text{ m})$

For the correct answer 1 point

$W = 0.34 \text{ J}$

(b)



(i) 2 points

For correctly plotting four of the five given points 2 points

(ii) 1 point

For correctly drawing a straight line that has at least two data points above the line and two points below the line 1 point

Question 2 (continued)

Distribution of points

(c) 4 points

For applying the correct kinematic equation to determine the acceleration — 1 point
$v^2 = v_0^2 + 2ax$

For correctly equating the slope of the graph to twice the acceleration — 1 point
Slope $= 2a$

For correct determination of the slope using points clearly on the best-fit line — 1 point
(Using data points not on the line does not receive credit.)
For example, using points on the graph shown:

$$\text{Slope} = \frac{(0.93 - 0.49)\text{m}^2/\text{s}^2}{(0.3 - 0.1)\text{m}} = 2.20 \text{ m/s}^2$$

For a numerical answer in the range 0.83 to 1.3 m/s^2 — 1 point
$a = 1.10 \text{ m/s}^2$

(d) 3 points

For correct identification of a valid alternative method — 2 points
For example, conservation of energy:

$$W = \frac{1}{2}m\left(v_f^2 - v_i^2\right)$$

$$W = \frac{1}{2}(0.65 \text{ kg})\left((1.08 \text{ m/s})^2 - (0.55 \text{ m/s})^2\right)$$

For the correct answer — 1 point
$W = 0.28$ J

(e) 2 points

For a reasonable answer based on the two values of work obtained — 1 point
For a correct and substantive explanation — 1 point
For example: The work calculated in (d) is less than the work calculated in (a). Part (a) includes only the positive work performed on the cart by the string. There could be energy dissipated due to friction, which is included when you calculate the actual change in kinetic energy in part (d).

Units 1 point

For correct units in all final numerical answers — 1 point

Question 3

15 points total — **Distribution of points**

(a) 4 points

For correctly applying Newton's second law — 1 point

$Ma = Mg - T$

For correctly applying a torque equation relating T and α — 1 point

$\tau = TR = I\alpha$

For correctly incorporating the relationship between α and a — 1 point

$TR = I\alpha = I\frac{a}{R}$

$T = I\frac{a}{R^2}$

Substituting into the equation for Newton's second law

$Ma = Mg - \frac{Ia}{R^2}$

$Mg = a\left(M + \frac{I}{R^2}\right)$

Substituting the given expression for I

$Mg = a\left(M + \frac{1}{R^2}\left(\frac{1}{2}MR^2\right)\right)$

$Mg = a\left(M + \frac{M}{2}\right) = \frac{3}{2}Ma$

For the correct answer — 1 point

$a = \frac{2}{3}g$

(b) 3 points

For applying conservation of energy — 1 point

For correctly including all three terms (gravitational potential, linear kinetic, rotational kinetic) — 1 point

$Mgh = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2$

Substituting $v = r\omega$ and the given expression for I

$Mgh = \frac{1}{2}MR^2\omega^2 + \frac{1}{2}\left(\frac{1}{2}MR^2\right)\omega^2$

$Mgh = \frac{3}{4}MR^2\omega^2$

For the correct answer — 1 point

$\omega = \sqrt{\frac{4gh}{3R^2}}$

Question 3 (continued)

	Distribution of points
Alternate solution	*Alternate points*
For correctly substituting the acceleration from part (a) into the kinematic equation	*1 point*
$v^2 = v_0^2 + 2a(y - y_0)$	
$v^2 = 2\left(\frac{2}{3}g\right)h = \frac{4gh}{3}$	
For substituting v into the expression $\omega = v/R$	*1 point*
$\omega = \frac{v}{R} = \frac{\sqrt{4gh/3}}{R}$	
For the correct answer	*1 point*
$\omega = \sqrt{\frac{4gh}{3R^2}}$	
Note: Another alternate solution, obtained by combining the time determined by kinematics with the expression relating angular impulse and change in angular momentum, would also be acceptable if correctly implemented.	

(c) 4 points

For applying the torque equation	1 point
For a correct expression for the torque due to friction	1 point
$\tau = I\alpha = -\mu MgR$	
$\frac{1}{2}MR^2\alpha = -\mu MgR$	
$\alpha = -\frac{2\mu g}{R}$	
For applying the appropriate rotational kinematic equation	1 point
$\omega = \omega_0 + \alpha t$	
For using the result of part (b) as the initial angular velocity	1 point
$\omega = \sqrt{\frac{4gh}{3R^2}} - \frac{2\mu g}{R}t$	

(d) 2 points

For correct use of Newton's second law and a kinematic equation	1 point
$Ma = \mu Mg$	
$a = \mu g$	
$v = at$	
For the correct answer	1 point
$v = \mu gt$	

Question 3 (continued)

Distribution of points

(e) 2 points

For correctly stating the condition for cessation of slipping — 1 point

$v = R\omega$

For correctly substituting results from parts (c) and (d) — 1 point

$$\mu g t = R\left[\sqrt{\frac{4gh}{3R^2}} - \frac{2\mu g}{R}t\right]$$

$$\mu g t = 2\sqrt{\frac{gh}{3}} - 2\mu g t$$

$$t = \frac{2}{3\mu}\sqrt{\frac{h}{3g}} = \sqrt{\frac{4h}{27\mu^2 g}}$$